NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

WARTIME REPORT

ORIGINALLY ISSUED
October 1942 as
Advance Restricted Report

THEORETICAL DISTRIBUTION OF LOAD OVER A SWEPT-BACK WING

By Doris Cohen

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

NACA

WASHINGTON

L - 221

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ADVANCE RESTRICTED REPORT

THEORETICAL DISTRIBUTION OF LOAD OVER A SWEPT-BACK WING

By Doris Cohen

SUMMARY

The load over an elliptical wing with 30° sweepback has been calculated by a method, based on vortex theory, which takes account of the chordwise distribution of lifting area. The theory indicates a 14-percent loss in total lift due to the introduction of sweepback, with the greatest loss taking place at the center of the span. An increase in concentration of load at the tips is also indicated. The results are compared with results previously obtained by somewhat simpler calculations based on the assumption of a single lifting vortex.

INTRODUCTION

Until recently, theoretical treatments of the effect of sweepback on the aerodynamic characteristics of a wing have failed to consider any deviation of the span loading from that of the corresponding straight wing. In a recent report (reference 1), the load over a swept-back wing is determined by considering the effect of a lifting line at the quarter-chord line of the wing on the flow at the three-quarter-chord line. A method of load determination has since been developed (reference 2) that takes into account the continuous chordwise distribution of lift. Application of this more accurate method to the case of a swept-back wing indicated (see reference 2) that the introduction of sweepback causes the lift at the center to fall considerably below that of the corresponding wing without sweepback. The calculations of reference 1 did not show this effect. Further calculations were therefore undertaken to determine the correct load distribution, with special attention given to the load at the middle of the span. The calculations were made for the case of a wing of aspect ratio 6 with an elliptical distribution of chord, the center line of which is swept back 30°.

The results obtained are compared with the data of reference 1.

METHOD OF OBTAINING THE LIFT DISTRIBUTION

The method of calculation of the lift distribution, described in detail in reference 2, consisted in replacing the wing and its wake by a continuous distribution of vortices and computing the induced vertical velocities caused by this vortex system at several points on the wing. It is evident that, in order to satisfy the boundary conditions, the induced velocities must be proportional to the slope of the surface at these points and, in particular, for a flat surface they must all be equal. The vortices coincide with the contour lines of the circulation function Γ, which, in turn, is obtained by integrating the lift back along the chord from the leading edge.

Points for which the downwash was calculated were taken along the quarter-chord line and the three-quarter-chord line, at the center section and at 30, 60, and 86.7 percent of the semispan. The lift distribution derived from two-dimensional theories resulted in a linear variation of downwash along the three-quarter-chord line except for a discontinuity at the center, where the downwash was infinite. A second approximation, designed to eliminate the peak in the downwash at the center, proved to be too far in the other direction. A third approximation gave again a linear variation of downwash, but with slightly lower values at the center than at the tip. Values for the quarter-chord points obtained for this same lift distribution fell along a line parallel to that for the three-quarter chord and approximately 8 percent below it. This result indicates a small amount of camber, about equal to the average camber of the straight elliptical wing used for comparison, but in any case negligible. It was assumed that interpolation between the third load distribution and the first (two-dimensional) approximation, at the same angle of attack, would be a fairly accurate solution to the problem, especially since the third approximation was already a close one. The curves presented are the result of this interpolation.

RESULTS AND DISCUSSION

Figure 1 shows the complete configuration of vortices determined for a flat swept-back wing without thickness. The vortex lines were derived from the lift distribution in such a way that adjacent lines enclose a fixed amount of lift; the concentration of lift in any region is therefore proportional to the density of the lines. The entire pattern is independent of angle of attack, except as the basic theory breaks down at large angles of attack.

In figure 2 is shown the span loading derived for the elliptical wing with 30° sweepback. The calculated load is compared with the elliptical load, which has been shown (reference 2) by the same method to be a reasonablt accurate assumption for an elliptical wing with no sweepback. At the same angle of attack of the two wings, measured in accordance with the thin-wing-section theory by the slope at the three-quarter-chord line, the area under the curve for sweepback is 86 percent of that under the ellipse, indicating a loss, due to the introduction of sweepback, of 14 percent of the total lift. This result is twice that obtained by Mutterperl for an airfoil of constant chord (reference 1), using rectilinear vortices concentrated on the quarter-chord line.

The effect of sweepback on the spanwise variation of the lift, indicated by the curves drawn for the same total lift, is in general the same as is given by Mutterperl's simplified treatment, except for the pronounced falling off of lift at the center. Because Mutterperl chose his downwash points at 50 percent of the semispan and beyond, no comparison of the results at the center is possible. The present method is, however, considered to be particularly valid in that region.

The present calculations are made for elliptical wings. In Mutterperl's work and in the experiments available for comparison, wings with constant chord distribution or straight taper were considered. In some tests (references 3, 4, and 5) the sweepback was effected by rotating the wing about an axis in the plane of symmetry, thus changing the section profile in the direction of the air stream as well as the chord distribution. Thus, no real check of the theory is available.

The following table is a summary of pertinent test data on the loss in total lift due to the introduction of sweepback. The values tabulated give the total lift on the swept-back wings, expressed as fractions of the lift on the corresponding straight wings. Theoretical values for the total lift for other than 30° sweepback were obtained by interpolation, on the assumption that the lift varies as the cosine of the angle of sweepback.

Angle of sweep-back (deg)	Theoretical values		Experimental data		
	Theory of reference 1 (rectangular chord distribution)	Theory of reference 2 (elliptical chord distribution)	Value	Remarks	Reference
20	0.97	0.94	0.96	Slightly rounded tips	3
23		.92	.91	Aspect ratio, 8.3	7
27½		.89	.96	No tip fairings; 2:1 taper	8 and 9
30	.94	.86	.87	No tip fairings	4
			.83	Corrected for aspect ratio	5

Unless otherwise noted, the wings were of constant chord and aspect ratio 6. The reason for the discrepancies among the test results is not understood, but it is possible that differences in plan form introduce first-order effects not predictable by potential-flow theory.

Pressure-distribution tests have been made by Knight and Noyes (references 3 and 6) on rectangular wings with 20° sweepback. No measurements were made over the central 35 percent of the span, however, where the chief effect of the sweepback is to be expected. The incompleteness of the experiments, combined with the distortion of the chord distribution and of the section profiles introduced with the sweepback, makes the data unsatisfactory for checking the present results. Experimental verification of the dropping off of the lift in the center is therefore still needed.

CONCLUDING REMARKS

The effects of sweepback shown by the present analysis are similar to those shown in reference 1: Sweepback promotes higher concentration of load at the wing tips and reduces the total lift for a given angle of attack. The theoretical reduction of lift in the case of an elliptical chord distribution, aspect ratio 6, and 30° sweepback amounts to 14 percent of the load for the straight wing. This loss, which is about twice as large as would be expected from reference 1, results from a pronounced reduction of the load carried at the center of the wing, a factor which was not covered by the calculations of the reference. Available experimental data on sweepback are not considered to provide a conclusive check of the results presented. The accuracy of the theory should be checked by further tests, especially pressure-distribution measurements to determine whether or not the large loss of lift near the center actually occurs.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

REFERENCES

1. Mutterperl, William: The Calculation of Span Load Distributions on Swept-Back Wings. T.N. No. 834, NACA, 1941.

2. Cohen, Doris: A Method for Determining the Camber and Twist of a Surface to Support a Given Distribution of Lift. T.N. No. 855, NACA, 1942.

3. Knight, Montgomery, and Noyes, Richard W.: Span-Load Distribution as a Factor in Stability in Roll. Rep. No. 393, NACA, 1931.

4. Williams, D. H., and Halliday, A. S.: Experiments on Swept-back and Swept-forward Aerofoils. R. & M. No. 1491, British A.R.C., 1933.

5. Rossell, H. E., and Brand, C. L.: Swept Back Wings. Part VIII, Reports on Wind Tunnel Experiments in Aerodynamics. Smithsonian Misc. Coll., vol. 62, no. 4, 1916, pp. 55-73.

6. Knight, Montgomery, and Noyes, Richard W.: Span Load Distribution on Two Monoplane Wing Models as Affected by Twist and Sweepback. T.N. No. 346, NACA, 1930.

7. Wieselsberger, C.: Measurements on Wings with Sweepback and Warping. (Trans. from Results of Aerodynamic Test Plant at Göttingen, vol. II, 1923.) Memo. rep. No. 123, War Dept. Air Service, McCook Field, Ohio, 1924.

8. Anderson, Raymond F.: Determination of the Characteristics of Tapered Wings. Rep. No. 572, NACA, 1936.

9. Anderson, Raymond F.: The Experimental and Calculated Characteristics of 22 Tapered Wings. Rep. No. 627, NACA, 1938.

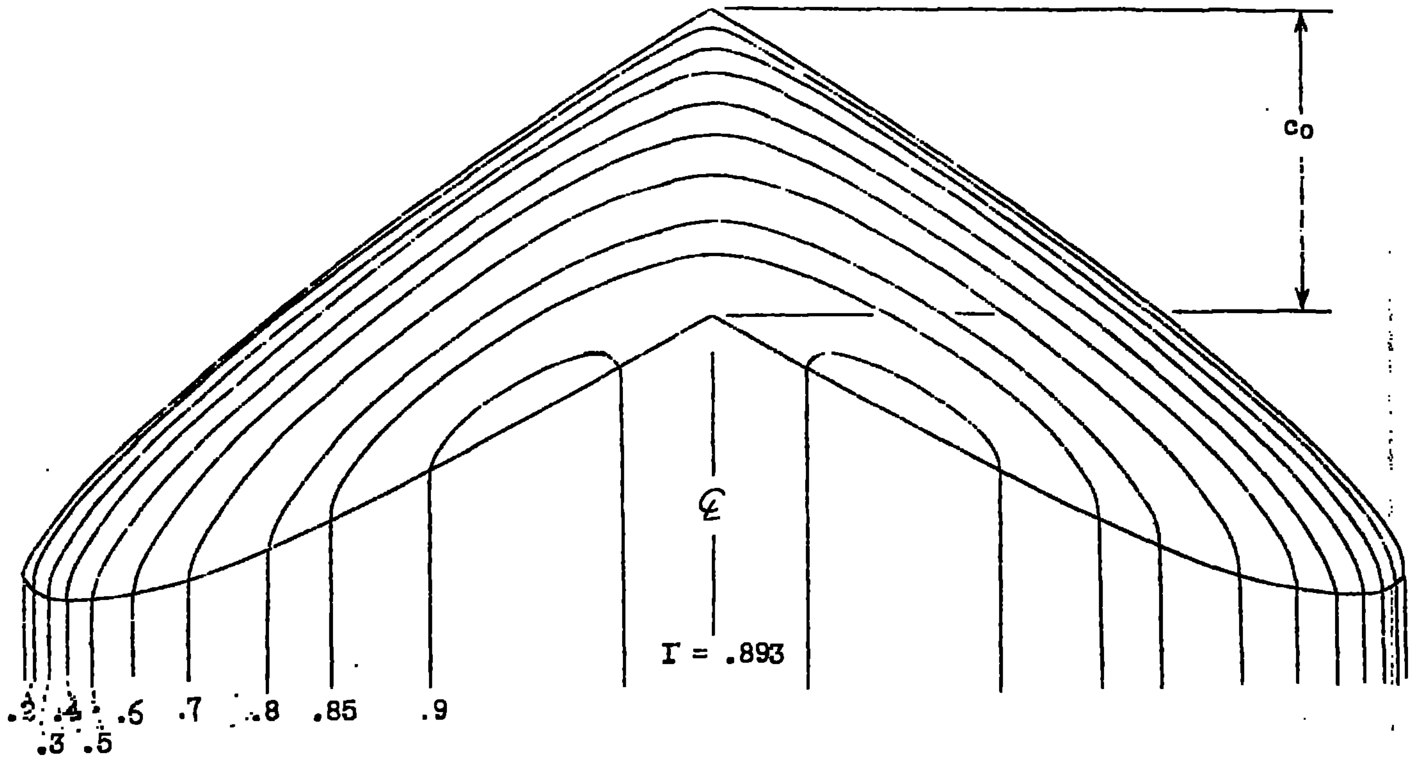

Figure 1.- Distribution of vorticity or circulation over elliptical wing, A = 6, swept back 30°. Density of the contour lines indicates concentration of lift. The numbers refer to the value of the circulation function Γ.

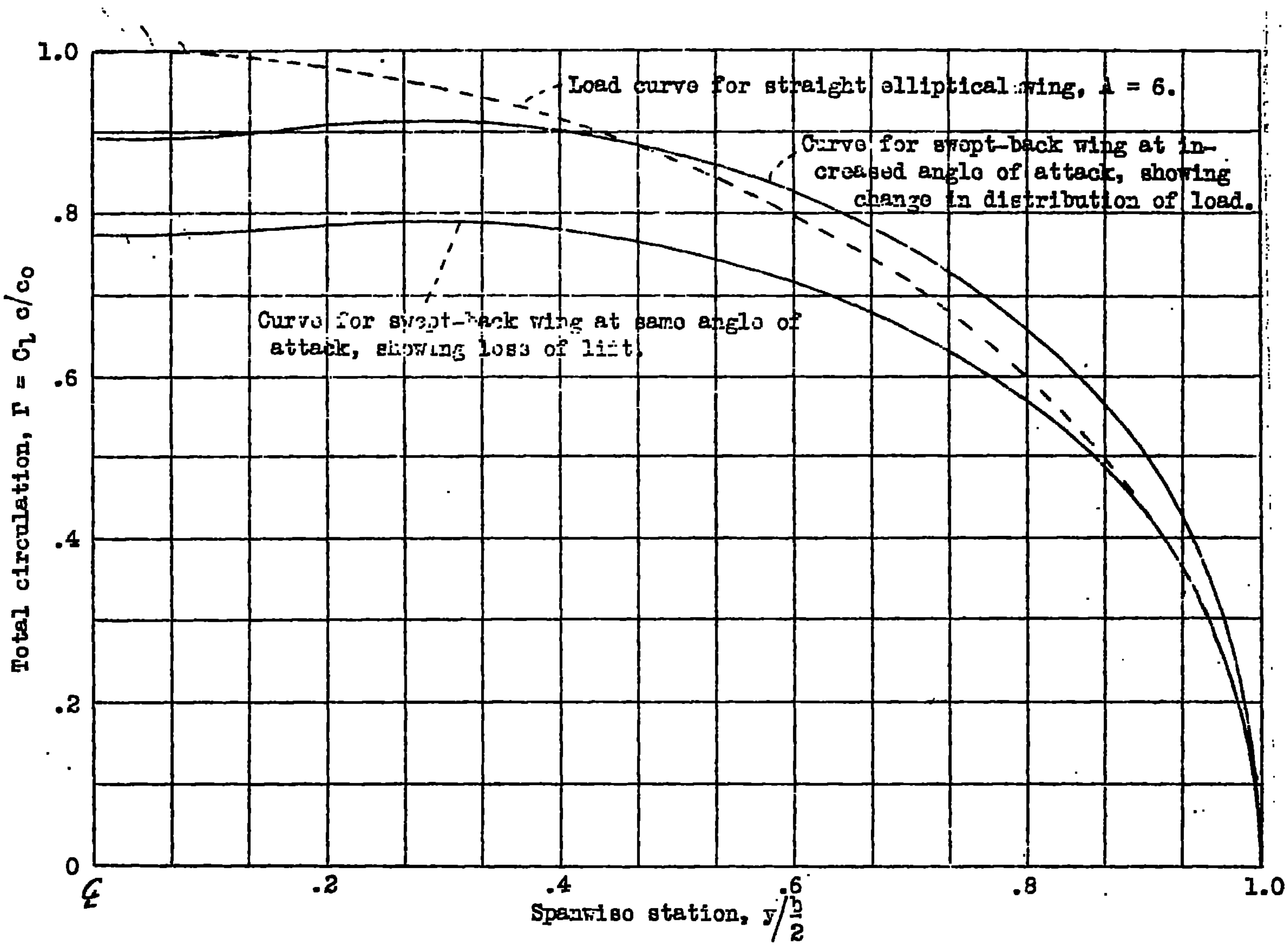

Figure 2.- Span-load curves for a wing with elliptical chord distribution, showing the effects of 30° sweepback.